A Foot Care Program for Diabetic Unilateral Lower-Limb Amputees

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OBJECTIVE — To assess the efficacy of a specialist foot care program designed to prevent a second amputation and to assess peripheral vascular disease (PVD) and peripheral neuropathy in diabetic unilateral lower-limb amputees.

RESEARCH DESIGN AND METHODS — Investigations were carried out in 143 diabetic lower-limb unilateral amputees referred to a subregional rehabilitation center for prosthetic care from a catchment area of ~3 million people. Peripheral vascular and nerve assessment, education, and podiatry were provided for each patient.

RESULTS — For the patients referred to the foot care program, there were no baseline differences between the patients who proceeded to a bilateral amputation ($n = 22$) and those who remained as unilateral amputees ($n = 121$) in their level of foot care knowledge and mean neuropathy scores. Mean ankle-brachial pressure index was significantly lower for the bilateral amputees (0.75 ± 0.04) compared with the unilateral amputees (0.90 ± 0.03, mean ± SEM, $P < 0.05$), but there was no difference in the level of oxygen in the skin. However, the level of carbon dioxide was significantly lower in patients with bilateral amputation (24.21 ± 2.16 vs. 31.20 ± 0.85 mmHg, $P < 0.03$). Overall, the establishment of a specialist foot care program made no impact on contralateral limb amputation (22 of 143, 15.4%) compared with matched patients without the program (21 of 148, 14%) over a 2-year outcome period for each patient.

CONCLUSIONS — PVD is more closely associated with diabetic bilateral amputation than neuropathy or level of foot care knowledge. Preventative foot care programs for diabetic unilateral amputees should therefore place greater emphasis on peripheral vascular assessment to identify patients at risk and on the development of timely intervention strategies.

Diabetes Care 24:216–221, 2001

Amputation of a lower limb is a devastating consequence of diabetes, and people with diabetes are 10–15 times more likely to have a lower-limb amputation (LLA) than nondiabetic individuals (1–3). The etiology of LLA involves contributions from peripheral vascular disease (PVD), peripheral neuropathy, minor trauma, infection, impaired wound healing, and limited joint mobility (4,5). These factors can lead to foot ulceration, gangrene, and, finally, amputation if appropriate intervention is not applied. In Pima Indians, the presence of vascular disease (assessed as medial arterial calcification, retinopathy, or nephropathy), neuropathy (assessed as absence of patellar tendon reflexes and impaired great-toe vibration perception threshold), and the degree of hyperglycemia are significant risk factors for LLA (6). More recently, Adler et al. (7) have shown that PVD (assessed by transcutaneous oxygen levels, ankle-brachial pressure index [ABPI], and diminished lower-limb pulses), insensitivity to cutaneous pressure sensation, and lower-extremity ulcers and previous amputation are associated with LLA. Their study showed that lower-limb amputees are more at risk of a second amputation and that various measures of peripheral vascular function are independent risk factors for LLA.

In addition, there is a greater incidence of LLA in men than in women (approximately two to three times) (1,8), and, after LLA, the prognosis for the remaining limb is poor. Within 4 years of the first amputation, ~50% of contralateral limbs are lost (9). Moreover, life expectancy is also dramatically reduced as a result (8).

A reduction in the incidence of first amputation in high-risk diabetic patients has been demonstrated using intensive programs of education (10) or specialized diabetic foot clinics (11,12). It is possible that such methodology, aimed at prevention of a contralateral amputation, may also be useful for diabetic unilateral lower-limb amputees.

Consequently, this study was designed to examine the efficacy of a focused foot care program for diabetic unilateral amputees in preventing amputation of the contralateral limb. The patients examined in this study were those referred to a subregional rehabilitation center for prosthetic rehabilitation. Peripheral vascular status and nerve function were also assessed in all patients to examine their association with any future amputation.

RESEARCH DESIGN AND METHODS

Patient characteristics

All new diabetic unilateral lower-limb amputee referrals to the rehabilitation center (serving a population base of 3 million people) were enrolled in the foot care program over a 2-year period between September 1993 and August 1995. This study was approved by the South Manchester Medical Research Ethics Committee. Patient characteristics including demographics, diabetes information, and ampu-

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Received for publication 19 July 2000 and accepted in revised form 24 October 2000.

Abbreviations: ABPI, ankle-brachial pressure index; LLA, lower-limb amputation; MNCV, motor nerve conduction velocity; PVD, peripheral vascular disease; $TcpCO_2$, transcutaneous partial pressure of carbon dioxide; $TcpO_2$, transcutaneous partial pressure of oxygen; TT, transtibial.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Table 1—*Characteristics of patients attending the foot care program associated with a 2-year outcome of bilateral amputation*

	Bilateral amputation	Unilateral amputation	*P*
n	22	121	
Sex (*n*)			NS
Male	19	82	
Female	3	39	
Age (years)	64.00 ± 9.89	65.43 ± 11.30	NS
Diabetes duration (years)	15.00 ± 11.69	14.24 ± 11.99	NS
Diabetes treatment (%)			NS
Diet	9.0	12.4	
Insulin	45.5	45.5	
Tablets	45.5	42.1	
Social categories (%)			NS
Upper	15	33.6	
Lower	85	66.4	
Ethnic origin (%)			<0.05
European	95.5	95.9	
South Asian	0	4.1	
Black	4.5	0	
Smoking status (%)			NS
Present or past smokers	80.9	75.6	
Nonsmokers	19.1	24.4	
Alcohol consumption (%)			NS
None	28.6	44.7	
<10 U weekly	61.9	37.7	
>10 U weekly	9.5	17.6	
Amputation site (%)			NS
Transfemoral	36.4	28.9	
Transtibial	63.6	66.1	
Partial foot	0	5.0	
Ulcer on foot (%)			NS
Ulcer	33.3	26.3	
No ulcer	66.7	73.7	
Foot deformity (%)			NS
Deformity (FDS ≥3/6)	36.4	28.3	
No deformity	54.6	71.7	
Edema in intact limb (%)			NS
Edema	50.0	45.3	
No edema	50.0	54.7	
Knowledge score (/18)	16.81 ± 1.28	16.17 ± 2.04	NS

Data are *n*, means ± SD, or %. FDS, foot deformity score.

tation information were recorded using a standardized form. Patient social categories were estimated using the Registrar General's categories for occupation (1 = professional, 2 = intermediate, 3N = skilled nonmanual, 3M = skilled manual, 4 = partly skilled, and 5 = unskilled). These were then separated in to upper (1, 2, and 3N) and lower (3M, 4, and 5) for the purpose of analysis. Patients were also assigned to the following broad ethnic groups for data comparison: European, South Asian, and black.

Clinical examination of the foot

The remaining foot was examined for the presence of ulceration, edema, and foot deformities. The severity of foot deformity was assessed using the foot deformity score and included the presence of small muscle wasting, hammer/claw toes, bony prominences, prominent Metatarsal heads, Charcot arthropathy, and limited joint mobility (positive prayer sign). For each of these conditions, a score of 1 was assigned if the deformity was present (≥3 of 6 indicates moderate/severe foot deformities).

Peripheral vascular and neurological assessments of the remaining limb

All assessments were made at a skin temperature ≥30°C, measured with a Mikron thermometer (Model M806-OC; Wyckoff, NJ) and maintained using a controllable heating pad within a leg trough. The patient values obtained were compared with laboratory values from nondiabetic age-matched control subjects (n = 17) and assigned as normal or abnormal. Abnormal values were determined from control mean values ± 2 SDs.

Peripheral vascular assessment. Patients were questioned and notes were examined regarding any history of PVD. A positive history included evidence of intermittent claudication, rest pain, angioplasty, and/or peripheral vascular surgery. Pulse palpation of the dorsalis pedis, posterior tibialis, popliteal, and femoral pulses was undertaken on the remaining intact limb, and abnormality was assigned if two or more of four pulses were present. ABPI was determined using a Doppler ultrasound machine (Sonicaid, Oxford, U.K.) and a portable sphygmomanometer (Accoson, Brighton, U.K.). A value of <0.8 indicated vascular insufficiency. Values ≥0.8 were subclassified as normal or calcified (if dorsalis pedis pressure was >280 mmHg). Transcutaneous partial pressure of oxygen ($TcpO_2$) and carbon dioxide ($TcpCO_2$) were measured at the foot dorsum using a transcutaneous pO_2/pCO_2 monitoring system (Radiometer; Crawley, Sussex, U.K.). The electrode combines a heating element, two temperature sensors, a Clark-type oxygen electrode, and Severinghaus-type carbon dioxide electrode in a single unit. Before each measurement, the system was calibrated. After calibration, the electrode was fixed at the skin surface, and generated heat was transferred to the skin surface to heat the skin to 43°C. This produced a local vasodilation to increase the permeability of the skin to oxygen and carbon dioxide, rendering a measurement at the skin surface possible. When the oxygen values had stabilized (usually 20 min), the values were recorded at 1-min intervals for a period of 5 min, and the mean value was taken as the partial pressure. The partial pressure of oxygen was abnormal if <25 mmHg (17); no values have been established for carbon dioxide levels.

Peripheral neurological assessment. Patients were asked about symptoms in their remaining limb, which were categorized using a modified neuropathy symptom score (NSS) (13). If the score was ≥5 of 9, the patient was deemed to have moderate/severe symptoms of neuropathy, and this was assigned as abnormal. The modified neurological disability score (NDS) (13) was assessed for each patient. This is a composite score derived from the assessment of pain, temperature, vibration sense, and Achilles reflex. A score of ≥3 of 5 (one limb) indicated neuropathy and was assigned as abnormal. Vibration perception threshold (VPT) was measured using the Neurothesiometer (Horwell, Wilford, Nottingham, U.K.) at the hallux and medial malleolus (two tests). A mean of three values >25 V indicated neuropathy and was assigned abnormal. Cutaneous pressure perception threshold (PPT) was determined using Semmes-Weinstein monofilaments (Gillis W. Long Hansens' Disease Center, Carville, LA) at the dorsal and plantar surface of the foot (two tests). Three filaments (4 [1 g], 5 [10 g], and 6 [75 g]) were used for assessment, and pressure perception was abnormal if the threshold was >5 (10 g). Common peroneal motor nerve conduction velocity (MNCV) was measured using the MS92a EMG machine (Medelec, Old Woking, Surrey, U.K.). Action potentials were recorded using surface electrodes placed at the Extensor Digitorum Brevis muscle, and the common peroneal nerve was stimulated (300 V intensity, 0.1 ms duration) to obtain a supramaximal stimulus. Stimulation was carried out at the head of the fibula and midway between the malleoli on the anterior surface of the limb. Skin temperature was recorded, length of nerve measured, and proximal and distal latencies recorded. The MNCV was then calculated, and values <40 m/s were assigned as abnormal. Temperature (hot) perception threshold (TPT) was determined using a forced-choice procedure with the Therm-aesthesiometer (model AZVU; Medical Instruments Department, VU Hospital, Amsterdam, the Netherlands) at the foot dorsum. A threshold of >2°C was considered abnormal for purposes of classification.

Table 2—*Peripheral vascular assessments of the remaining limb associated with a 2-year outcome of bilateral amputation*

	Bilateral amputation	Unilateral amputation	P	Control subjects (means − 2 SD)*
History of PVD (%)				NA
Positive/negative	63.6/36.4	61.9/38.1	NS	
Palpitation pulse	2.00 ± 1.05	2.28 ± 1.04	NS	3.90 − 0.63 = 3.27
ABPI (mmHg)	0.75 ± 0.20	0.90 ± 0.31	0.048	1.2 − 0.4 = 0.8
Abnormal ABPI (%)				NA
<0.8 or calcified/ normal	75.0/25.0	47.4/52.6	0.038	
TcpO_2 (mmHg)	41.12 ± 18.60	45.88 ± 18.07	NS	62.25 − 23.00 = 39.25
TcpCO_2 (mmHg)	24.21 ± 10.11	31.20 ± 9.30	0.027	NA

Data are % or means ± SD. *Normal lab values for age-matched nondiabetic/nonamputee control subjects (n = 17) were determined on the basis of means − 2 SD, an accepted value for the cutoff for normal range.

Foot care program (education, podiatry, and follow-up)

Levels of foot care knowledge were also assessed using a standardized questionnaire before any of the assessments were done (out of 18). This was done so that the explanation of the tests and specific problems could be individually tailored for each amputee. At all stages, emphasis was placed on the clear explanation of tests to the patients and extrapolation to everyday events. Patients were also given education leaflets with explanation of specific points relating to individual problems and the opportunity to watch videos. Podiatry needs were addressed, and, if necessary, liaison with local podiatry services was established to ensure that patients had regular appointments. It was also ensured that patients had knowledge of and, if possible, access to appropriate hosiery and foot wear.

Records were maintained regarding podiatry/nursing care referrals, self-care/caregiver details, and general practitioner/hospital consultant details. If any foot problems were found, such as ulcers, they were treated, and ulcer information and treatment was recorded. Letters were sent to the general practitioners regarding the findings. The patients were seen at three monthly intervals until the completion of their rehabilitation at the center. On each visit, the patient saw the foot care nurse (N.J.), the rehabilitation nurse (S.J.), and the podiatrist (J.G.) for follow-up care and assessment. They were also given the foot care line telephone number (N.J.) for any problems. Neuropathy and vascular status were also reassessed at 1 and 2 years, and any changes were reported to the relevant health care professional.

Outcome analysis

Outcomes for contralateral LLA and death were examined for the 143 patients enrolled in the foot care program for a 2-year period after their initial assessment. These outcomes were compared with diabetic unilateral lower-limb amputees (same 2-year outcome period) who were referred to the Disablement Services Centre between January 1990 and December 1991, before the establishment of the diabetic amputee foot clinic. These patients (n = 148) had essentially the same prosthetic care as the patients referred between September 1993 and August 1995 but did not have access to a specialist foot care program.

Statistical analysis

Data were either expressed as number of occurrences or categories and were compared using the χ^2 test or as means ± SD and compared using Student's two-tailed unpaired t test, as appropriate (Excel 2000). A difference of $P < 0.05$ was considered statistically significant.

RESULTS — For the 143 patients attending the foot care program, there were no differences in any of the demographic characteristics between the patients who went on to bilateral amputation and those who did not (Table 1). Of all the patients presenting at the clinic, 27% had an ulcer on the remaining foot, demonstrating the extremely high-risk status of these patients regarding second amputation. However, almost all patients attending the foot clinic had good general foot care knowledge, as assessed by the simple questionnaire (Table 1). A significant difference was found for ethnic origin, but the percentages reflect only one black patient and five South Asian patients seen at the clinic, so it is unclear if ethnicity is a clinically significant determinant of second amputation.

When expressed as mean values, the only significant differences found for peripheral vascular function measurements between the two groups of patients were for ABPI and TcpCO_2 (Table 2). When the

Table 3—*Peripheral neurological assessments of the remaining limb associated with a 2-year outcome of bilateral amputation*

	Bilateral amputation	Unilateral amputation	*P*	Control subjects (means ± 2 SD)*
NSS (of 9)	3.45 ± 2.65	3.95 ± 2.92	NS	0.00 + 0.00 = 0.00
NDS (of 5)	3.33 ± 1.32	3.61 ± 1.38	NS	0.8 + 1.84 = 2.64
VPT (Hallux [V])	26.64 ± 13.74	28.26 ± 12.49	NS	8.71 + 8.77 = 17.47
VPT (Medial Malleolus [V])	27.68 ± 14.52	29.20 ± 13.01	NS	10.11 + 10.41 = 20.52
PPT (dorsum)	4.76 ± 1.04	4.93 ± 1.13	NS	4.00 + 0.00 = 4.00
PPT (plantar)	5.19 ± 0.98	5.33 ± 1.10	NS	4.29 + 1.18 = 5.47
MNCV (m/s)	34.63 ± 6.38	36.07 ± 4.84	NS	47.58 − 6.18 = 41.40
MNCV not obtained because of (%):				
Muscle wasting	22.2	21.5		
Edema	27.8	18.7		
TPT (dorsum [°C])	4.67 ± 4.35	5.72 ± 4.48	NS	0.59 + 0.53 = 1.12

Data are means ± SD or %. *Normal lab values for age-matched nondiabetic/nonamputee control subjects (*n* = 17) were determined on the basis of means ± 2 SD, an accepted value for the cutoff for normal range.

data were transformed to normal and abnormal values, the only significant difference found was for abnormal ABPI (Table 2). Of patients who went on to have a contralateral amputation, 75% had an abnormal ABPI at baseline, whereas only 48% of those who remained as unilateral amputees had abnormal ABPI.

There were no differences at all in any of the neurological tests undertaken when expressed as either mean values (Table 3) or abnormal values (data not shown).

Finally, the 2-year outcomes for bilateral amputation for patients attending the foot clinic and those referred to the center before the establishment of the foot clinic were not significantly different (Table 4). Of the 143 patients who attended the foot clinic, 22 (15.4%) went on to have a contralateral amputation, and of the 148 patients who did not attend the clinic, 21 (14.2%) went on to have a contralateral amputation (not significantly different). Over the 2-year outcome period, 27 patients died in the group attending the foot clinic, and 39 patients died in the group who did not attend the clinic (not significantly different) (Table 4). There were no differences in the baseline levels of amputation in the two groups. The only significant difference between the patient groups was their age (i.e., patients attending the foot clinic were slightly younger).

CONCLUSIONS — It was not possible to demonstrate a significant reduction in the bilateral amputation rate in diabetic unilateral amputees, despite the establishment of the foot clinic at the rehabilitation center.

The establishment of the foot clinic at the Disablement Services Center was useful in the implementation of care programs for the attendees. Any problems found (such as foot ulcers on the remaining limb) were addressed immediately, and community care was established, if not in place already. The results from the neurovascular assessments were also sent to the patient's family practitioner. However, the development of the specialized foot care program had no impact on the contralateral amputation rate over a 2-year follow-up period. Many of the patients had good knowledge of diabetic foot problems on arrival at the clinic, but 27% of these still presented with ulcers on the remaining foot. It was not possible to assess the efficacy of this clinic at reducing foot ulcer rate, because the relevant ulcer information was not documented in the notes of the patients referred to the center before the clinic was established.

Because the only neurovascular tests that were associated with bilateral amputation were primarily vascular, this study emphasizes the need for the prevention or reversal of PVD in people with diabetes. Previously, it has been shown that an aggressive wound-care protocol, including revascularization, helped to heal chronic ulceration in 75% of patients and save limbs in 83% of patients, emphasizing the importance of vascular intervention (14). The problems of accurately assessing peripheral vascular function are numerous, especially that of TcpO_2 measurement, as shown by Boyko et al. (15). However, a TcpO_2 value <30 mmHg has been shown to be an independent predictor of foot ulceration in diabetes (16). The finding of a significant difference in skin CO_2 levels between the bilateral and unilateral diabetic amputees studied here requires further investigation. There is evidence in the literature that alterations in acid/base balance can lead to altered vascular and nerve function (17,18).

In a retrospective study, Deerochanawong et al. (19) also found the prevalence of PVD in patients with a major limb

Table 4—*Comparison of data for patients seen in the foot clinic to those referred to the rehabilitation center before the establishment of the foot clinic*

	Patients referred before clinic (1/90–12/91)	Patients seen in clinic (9/93–8/95)	*P*
n	148	143	
Age (years)	67.81 ± 9.99	65.20 ± 11.07	0.038
Diabetes duration (years)	12.56 ± 12.70	14.35 ± 11.91	NS
Sex (*n*)			
Male	105	101	
Female	43	42	NS
Amputation site (*n*)			
Transfemoral	44	43	
Transtibial	103	94	
Partial foot	1	6	
2-year outcomes (*n*)			
Bilateral amputation	21 (14.2%)	22 (15.4%)	NS
Number of deaths	39	27	NS
Bilateral amputation and death	3	1	NS

Data are *n*, means ± SD, or *n* (%).

amputation to be 97% and that of peripheral neuropathy to be 68%. However, it is not clear exactly how the vascular disease and neuropathy were classified.

In abstract form only, Foster et al. (20) have shown that specialized foot care for lower-limb amputees can reduce the amputation rate of the contralateral limb in a small group of patients based at their foot clinic. Their results may reflect an improved access to vascular intervention than that available to many of the patients in this study or more neuropathic patients. At the time of this study, access to full vascular assessment and intervention varied between districts.

One of the main problems with this foot care program was the limited follow-up possible for these patients, and continuing foot care was in their own local districts. However, as previously stated, the main associations with second amputation were vascular in nature, and appropriate vascular intervention is required for these patients, whether it is surgical or pharmacological. The overrepresentation of males compared with females in this amputee population corresponds well with other reported data (1,8). Past and present smoking was remarkably prevalent in all patients, and smoking cessation clearly is important for such patients.

Other factors, such as dyslipidemia, high HbA_{1c}, and smoking, are also important in both the development of PVD and peripheral neuropathy and, consequently, lower-limb foot problems in diabetes (21–24).

Two out of three primary amputations in this study were transtibial (TT). This reflects the more distal vascular disease associated with diabetes, but preference is given to TT amputation also because this leads to improved postamputation mobility (because knee preservation is an important factor for better rehabilitation) (25).

In conclusion, PVD is more closely associated with diabetic bilateral amputation than neuropathy or level of foot care knowledge. This is in agreement with other studies emphasizing the greater importance of PVD in amputation compared with its influence in foot ulceration in diabetes (7,16,26). The importance of neuropathy assessment for identifying the at-risk diabetic foot is evident from many studies. However, this type of identification is needed relatively early in the course of diabetes. The study reported here shows that in these unilateral amputee patients, foot screening and education aimed at neuropathy alone is not sufficient to prevent contralateral amputation. Preventative foot care programs and strategies for diabetic unilateral amputees should therefore place greater emphasis on peripheral vascular assessment to identify patients at risk and likely to benefit from timely intervention.

Acknowledgments— This study was supported by the Department of Health, London, U.K.

This work was presented in abstract form at the American Diabetes Association Annual Meeting, which was held in San Antonio, Texas, in June 2000.

We would like to thank Sue Sheehan and Donna Bingham-Hind for their help in identifying patients at the Withington Disablement Services Centre and Julie Morris for statistical advice.

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